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COLUMN PERMEABILITY AND FLOOD LEACHING TESTS ON VARIOUS MIXTURES OF HEAP LEACHED CRUSHED ROCK AND IRON HYDROXIDE-GYPSUM SLUDGE FROM AGNEW LAKE MINES - PRELIMINARY REPORT

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by

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ABSTRACT

Permeability and column leaching tests under flooded conditions of various leached crushed rock and iron hydroxide-gypsum sludge sample mixtures from Agnew Lake Mines were conducted to determine their effluent quantity and quality as a function of time. It was found that the permeability of the sludge-rock mixtures was an order of magnitude lower than that of the pure crushed rock. The leaching tests indicated that under flooded conditions the pH of the effluent remained fairly constant with time. No evidence of continued sulphur oxidation was observed in the tests and the effluent quality was primarily governed by the presence and dissolution of gypsum in the sample material. Ra-226 was dissolved from the crushed rock, its concentration being moderated by the pH and sulphate ion concentration. The Ra-226 concentration in the leachate decreased with volume throughput.

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INTRODUCTION

Agnew Lake Mines, located about 50 km northwest of Sudbury, Ontario produces uranium by in situ leaching of broken ore in underground stopes and heap leaching of crushed ore on the surface. The heap leach pile contains about 2.0 million tonnes of crushed rock spread over an area of 8 hectares (20 acres). The mine produces no solid tailings but only neutralized mill effluent in the form of iron hydroxide-gypsum sludge, which is discharged to a waste management area. This system, known as the tailings pond, covers an area of 28 hectares (70 acres). It is estimated that there will be approximately 0.45 million m^3 (16 million ft^3) of sludge generated during the present production life of the mine. After cessation of its current milling activities, the mine plans to close out the facility and has proposed to move the heap leach pile to the tailings pond where the crushed rock will be mixed with the sludge and deposited into the tailings pond.

After abandonment of the waste management facility, both the permeability of the rock-sludge mixture and its leaching characteristics will govern the effluent load to the surrounding environment. Laboratory experiments were, therefore, conducted to determine the permeability and leachate characteristics of various rock-sludge mixtures in column permeameter tests. The leaching tests described in this report were conducted under flooded leach conditions. This effectively precluded the availability of oxygen and reduced the oxidation of metal sulphides which might have been present in the crushed ore. The results reported here for 0 and 30% volumetric sludge-rock mixtures are preliminary and will be presented in more detail in a follow-up report. Further experiments are also being conducted to examine the leaching of similar material under trickle leach conditions.

EXPERIMENTAL

Crushed rock samples from the surface heap leach pile and sludge samples from the tailings pond were collected at various locations. These were then homogenized separately to provide representative samples. Five column permeameters, each consisting of a 76.2 cm (30 in) high and 12.7 cm (5 in) inner diameter plexiglass tube, were set up as shown in Fig. 1. The first column contained a 10 kg homogenized rock sample (0% sludge) and the remaining four a homogenized mixture of 10 kg of the rock sample and 10%, 20%, 30% and 50% sludge by volume, respectively. The material was placed in the column between two layers of coarse Ottawa sand, fibreglass screen and glass wool filter. Rock sizes greater than 10 cm (4 in) were excluded from the test because of the size limitations of the permeameter tubes. Values of grain and bulk densities, total moisture content and other design data are given in Table 1.

Column permeability tests were conducted with a constant water head maintained at 15-20 cm (6-8 in) above the material in the tubes. The flow through the columns was monitored at regular intervals and the permeability was calculated using the relationship:

$$K = \frac{Q}{A.\frac{dH}{dL}} \qquad \text{Eq 1}$$

where, K = permeability of the medium, cm/sec

Q = flow rate, mL/sec

A = cross-sectional area of the tube, cm^2

dL = length of material column, cm

dH = water head, cm

Daily composite samples of the leachate were collected from the columns and were analyzed for pH, electrical conductance, acidity, hardness,

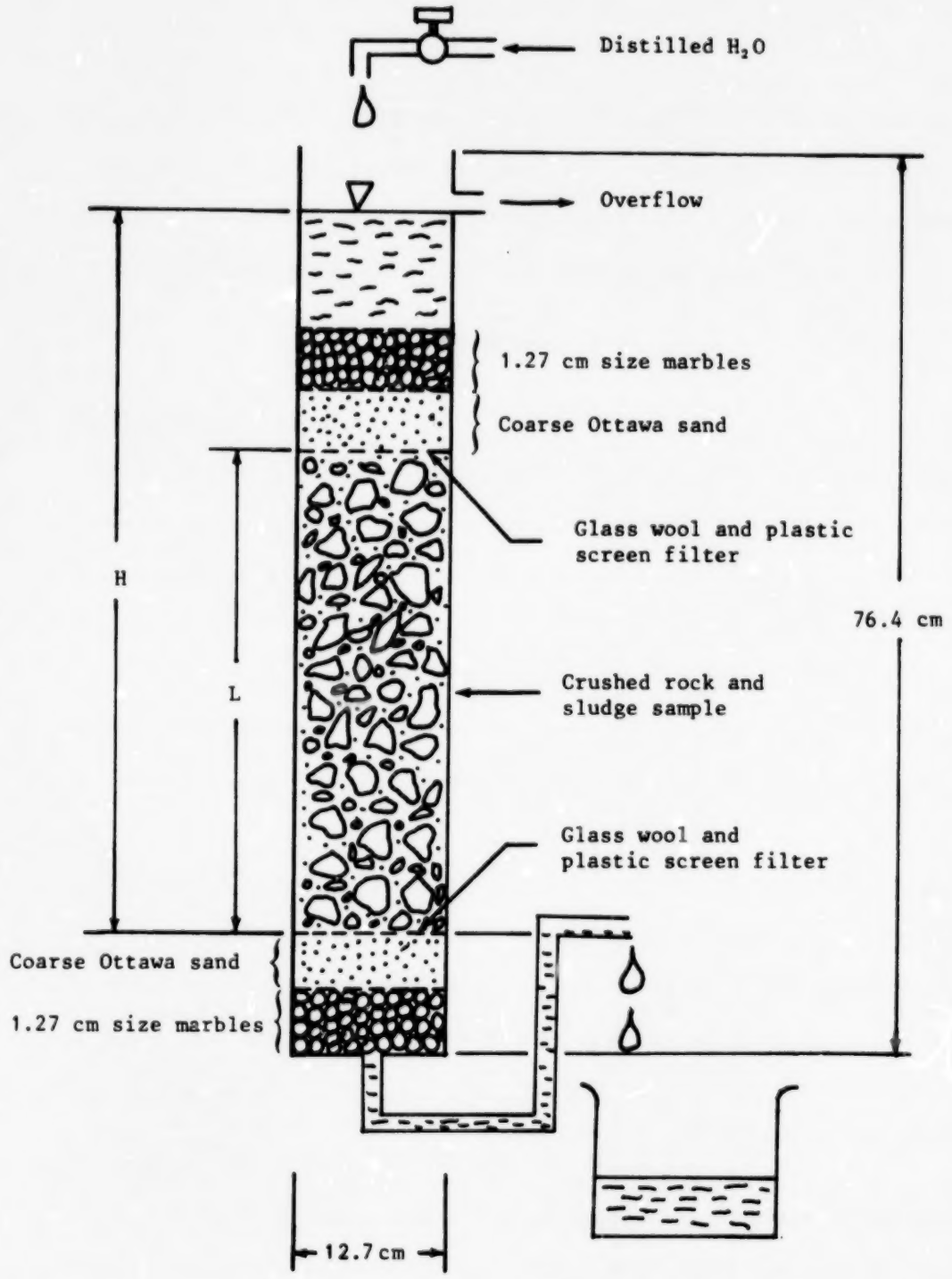

Fig. 1 - Column permeameter.

Table 1 - Heap leach rock and sludge data

Moisture content of ore = 4.84% (wt)
Moisture content of sludge = 78.8% (wt)
Pore volume = 30%
S.G. of ore (grain) = 2.68
S.G. of ore (bulk) = 1.89
S.G. of sludge = 1.21
Design based on sludge S.G. = 1.089
Volume of 10 kg of ore = 5.29L
Void volume = 1.59L

	% volume sludge (design)	wt. of ore kg	wt. of sludge kg	% sludge actual (volume)	Volume of sludge L	Residual pore volume L	Moisture contents of solids plus pores, L	Average moisture L
1	0	10	0	0	0	1.59	2.07	
2	10	10	0.58	9.06	0.48	1.11	2.05	
3	20	10	1.16	18.12	0.96	0.63	2.03	2.04 ±0.03
4	30	10	1.73	27.03	1.43	0.16	2.01	
5	50	10	2.90	45.31	2.40	Nil	2.77	2.77

NH_4^+, NO_3^-, SO_4^{--}, Ca^{++}, Fe(total) and Ra-226. Standard chemical and radioisotope procedures were used for the analyses. The samples were collected and monitored for a period of five months, the sample frequency being adjusted to a weekly composite, once the effluent quality had stabilized.

RESULTS AND DISCUSSION

PERMEABILITY

Figure 2 shows the variation of permeability for various rock and sludge mixtures as a function of time. Initially, the permeability of the crushed rock sample (0%) was an order of magnitude higher ($2\text{-}4\times10^{-4}$ cm/sec) than that of the rock-sludge mixtures ($1\text{-}4\times10^{-5}$ cm/sec), ranging from $\sim4\times10^{-5}$ cm/sec for 10% sludge to $\sim1.3\times10^{-5}$ cm/sec for 50% sludge mixtures. The lower permeability observed for the crushed rock and sludge mixture is thought to be caused by the fine-grained material in the rock combining with the precipitated sludge material.

With time the permeability of the pure crushed rock decreased as the associated fines percolated to the bottom of the bed thereby decreasing the flow. For the rock sludge mixtures, however, the permeability slightly increased with time due to increased channelling caused by the dissolution of gypsum from sludge as the water percolated through it.

LEACHING

Figures 3 and 4 show the total cumulative flow and flood leaching results for 0% and 30% samples as a function of time. Results for Ra-226 analyses are shown in Table 2.

During the test period, a total of 200 and 60 pore volumes of moisture passed through the 0% and 30% columns, respectively, the difference in flow resulting from the different permeabilities of the two mixtures.

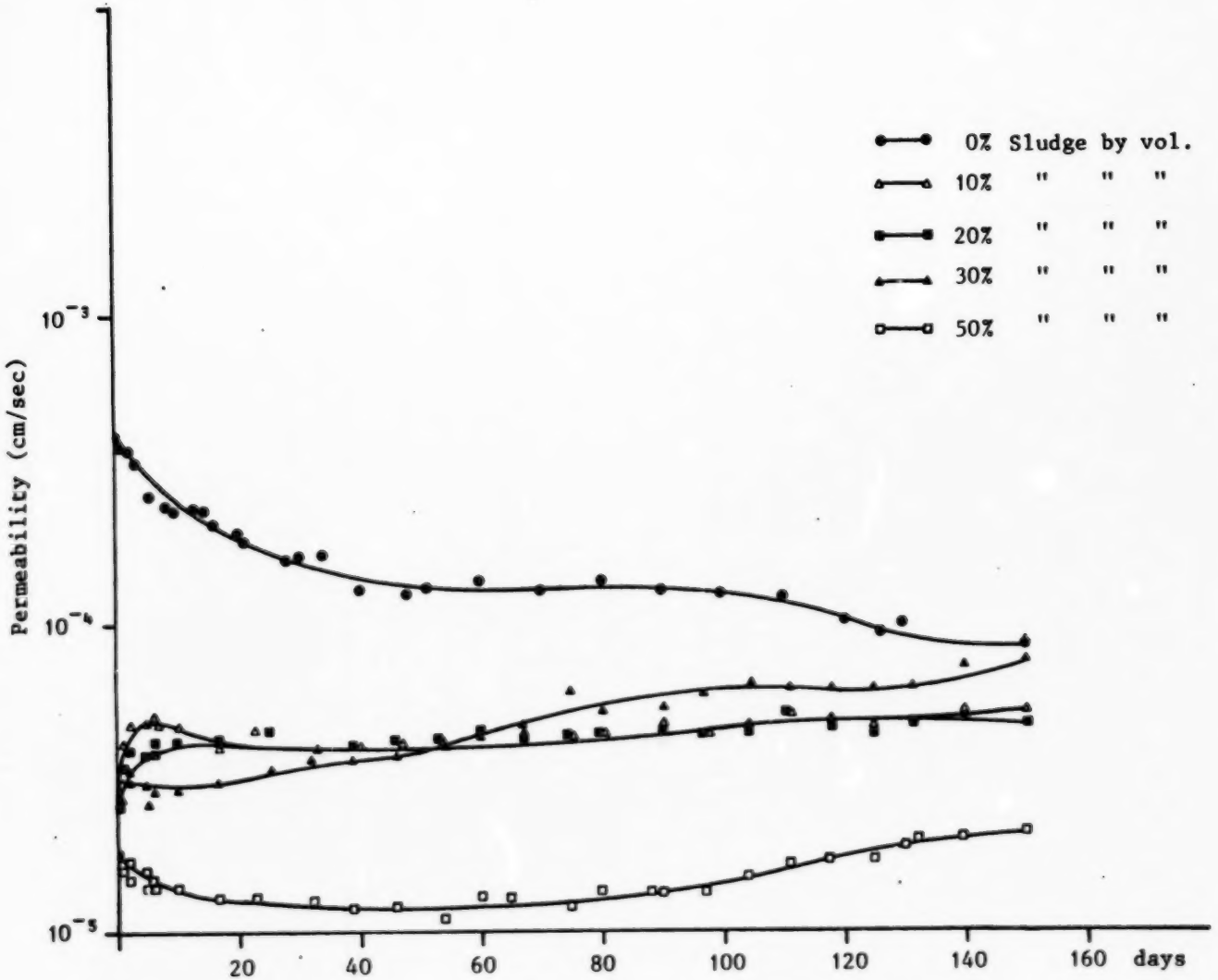

Fig. 2 - Variation of permeability versus time.

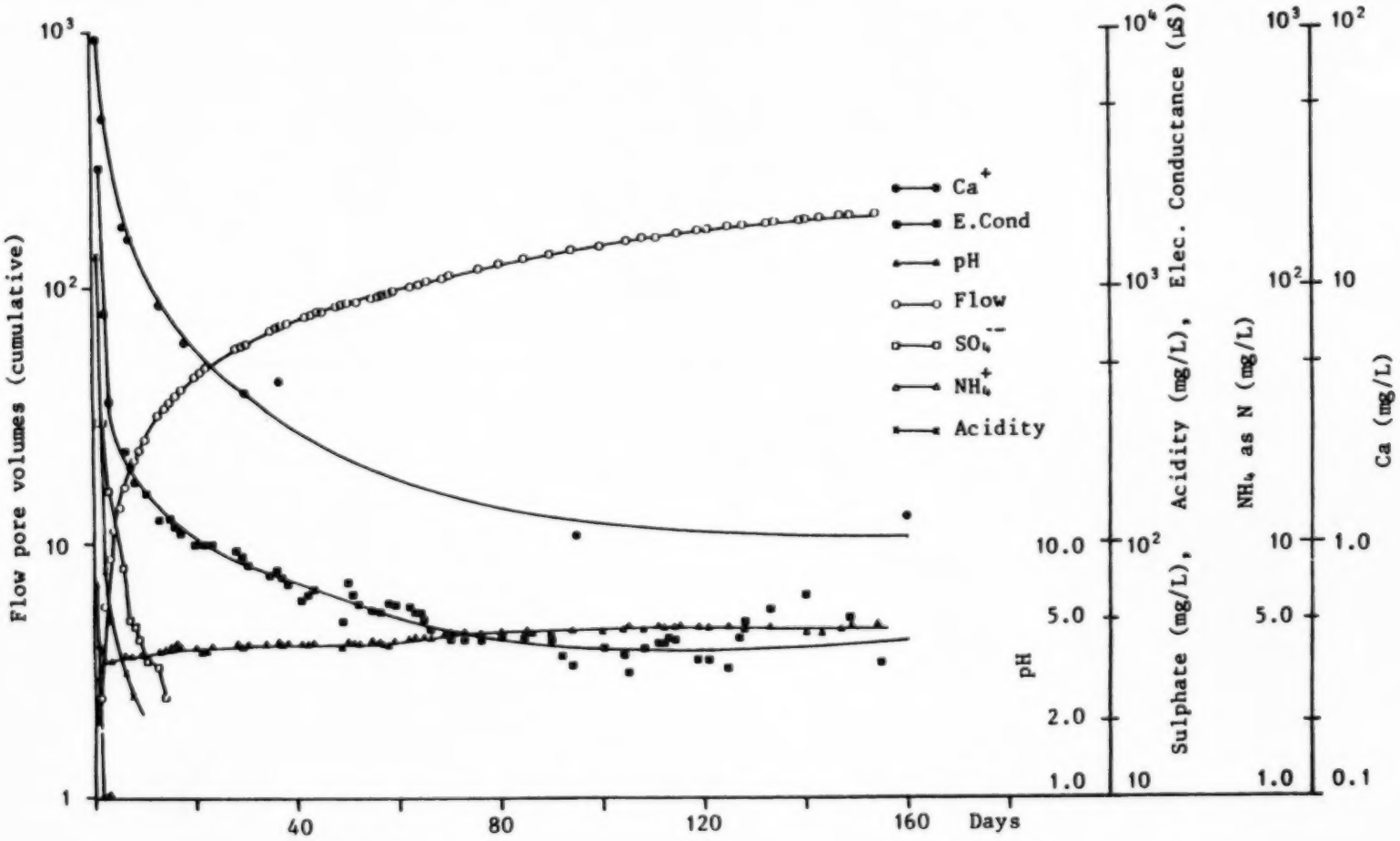

Fig. 3 - Concentrations of various ions in the flood leachate and total cumulative flow for crushed rock sample (0%) as a function of time.

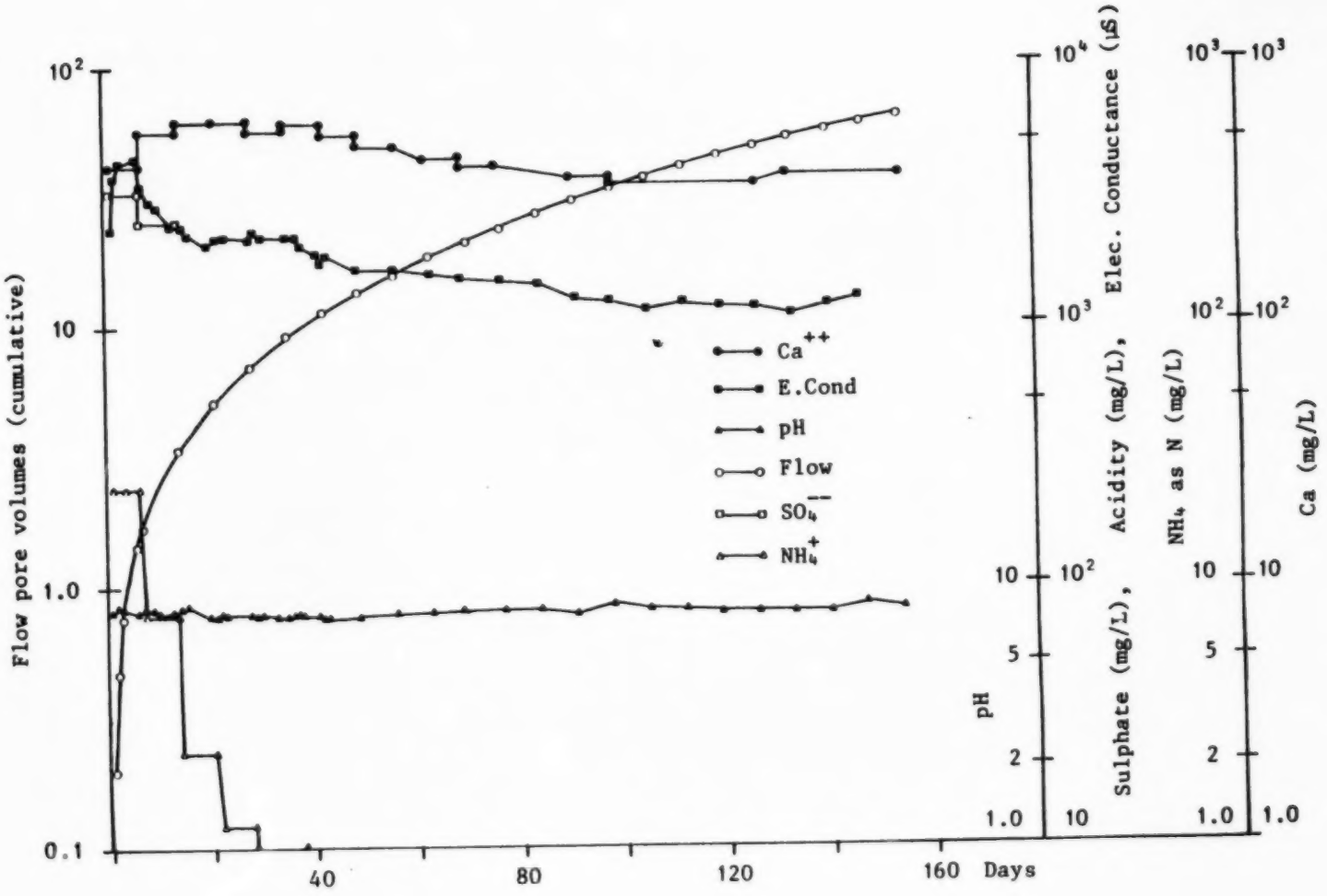

Fig. 4 - Concentrations of various ions in the flood leachate of total cumulative flow for crushed rock and sludge sample (30%) as a function of time.

Table 2 - Ra-226 concentrations, Bq/L (pCi/L) as a function of pore volume changes for leachates from 0% and 30% samples.

	Total flow, pore volume	Ra-226 concentration, Bq/L	(pCi/L)
	4	4.37	(118)
	8	3.33	(90)
0%	15	3.55	(96)
Crushed rock	17	4.22	(114)
	20	4.41	(119)
	200	2.33	(63)
	0.9	2.04	(55)
30%	2.5	1.70	(46)
Crushed rock	4.0	0.89	(24)
+ 30% sludge	8.0	0.85	(23)
by volume	10.0	0.92	(25)
	60.0	0.67	(18)

In the 0% test, except for the initial period, there was little change in pH. The initial pH of the leachate was low (~2) because of the presence of acid in the sample. This was completely flushed out after 20 days or about 50 pore volumes. Hereafter, the pH increased gradually to 4.6 and remained more or less uniform. During the initial 25 pore volume changes, all of the chemical concentrations decreased significantly, the NH_4^+ dropping to below 1 mg/L, the acidity falling from 1400 to 20 mg/L, electrical conductance from 3000 to 150 µS, SO_4^{--} from 2800 to 35 mg/L and Ca^{++} from 90 to 10 mg/L. After 60 days or 100 pore volume changes, the electrical conductance and Ca^{++} concentration had reached constant values of 40 µS and 1 mg/L, respectively.

No evidence of additional pyrite oxidation or mineral dissolution was detected.

For the 30% samples, the pH remained fairly constant around 8 throughout the experiment. This suggests that there is enough residual alkalinity in the sludge to neutralize the acid present in the crushed rock. No acidity was observed in the leachate throughout the experiment. Ammonia was flushed out of this system in 30 days or 7 pore volume changes. Electrical conductance followed the trends of gypsum dissolution from the sludge. Calcium concentrations in the leachate varied from 600 mg/L at the start of the experiment to around 400 mg/L at the end after 60 pore volume changes. No evidence of pyrite oxidation was observed during this test.

The experiments indicate that Ra-226 is gradually dissolved from the crushed rock material, its solubility being controlled by the pH and sulphate ion concentration present. Ra-226 concentrations in the leachate of the rock sludge-rock mixtures were found to be about half those of the pure rock. Concentrations also decreased with time.

Results for 10, 20 and 50% and for trickle leach conditions are being analyzed and will be reported separately.

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